Detrital U-Pb Zircon Dating of Lower Ordovician Syn-Arc-Continent Collision Conglomerates in the Irish Caledonides

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Abstract

The Early Ordovician Grampian Orogeny in the British Isles represents a classic example of collision between an oceanic island arc and a passive continental margin, starting around 480 Ma. The South Mayo Trough in western Ireland preserves a complete and well-dated sedimentary record of arc collision. We sampled sandstones and conglomerates from the Rosroe, Maumtrasna and Derryveeny Formations in order to assess erosion rates and patterns during and after arc collision. U-Pb dating of zircons reveals a provenance dominated by erosion from the upper levels of the Dalradian Supergroup (Southern Highland and Argyll Groups), with up to 20% influx from the colliding arc into the Rosroe Formation, but only 6% in the Maumtrasna

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Formation (~465 Ma). The dominant source regions lay to the northeast (e.g. in the vicinity of the Ox Mountains, 50 km distant, along strike). The older portions of the North Mayo Dalradian and its depositional basement (the Annagh Gneiss Complex) do not appear to have been important sources, while the Connemara Dalradian only plays a part after 460 Ma, when it supplies the Derryveeny Formation. By this time all erosion from the arc had effectively ceased and exhumation rates had slowed greatly. The Irish Grampian Orogeny parallels the modern Taiwan collision in showing little role for the colliding arc in the production of sediment. Negligible volumes of arc crust are lost because of erosion during accretion to the continental margin.

Keywords: Collision; Erosion; Zircon; Caledonides; Grampian

Introduction

Collision events between oceanic island arcs and passive continental margins are an integral part of the Wilson cycle and often precede continent-continent collision events. The process of arc accretion is an essential stage in the building and maintenance of continental crustal volumes because geochemical evidence indicates that most crust is formed in subduction settings (Rudnick, 1995) but that 40% of the total output is in oceanic arcs that need to be accreted to the continents if it is to be preserved (Clift et al., 2008). As well as accreting crust the collisional orogeny provides a method by which crust may be lost back to the upper mantle because erosion of sediment from the mountains delivers material to subduction trenches and can result in significant crustal loss (von Huene and Scholl, 1991).

The patterns of erosion are dependent on the nature of strain accommodation between the arc and the colliding passive margin. Collision of the Indian passive margin with the active margin of Asia in the Eocene seems to have largely driven uplift and erosion of the arc margin (Aitchison et al., 2002; Wu et al., 2007). In contrast, collision between the Luzon Arc and the Chinese passive margin in Taiwan has generated a thrust stack dominated by imbricated passive margin metasedimentary rocks (Suppe, 1981). The accreting arc is exposed as the topographically modest Coast Ranges in the east of the island, which contribute only a fraction of the total modern sediment flux (Dadson et al., 2003). Moreover, provenance analysis of the early syn-collisional sedimentary rocks indicates that these too are largely derived from the reworked passive margin (Dorsey, 1992).

Although the process of arc-continent collision has long been recognized in modern and Neogene oceans (e.g. in Taiwan (Suppe, 1984), in New Caledonia (Aitchison et al., 1995) and Kamchatka (Konstantinovskaia, 2001)), the identification of such processes in the ancient record is less well documented. Good examples are known from the Urals (Brown et al., 2006), but here we focus on the classic example of Connemara in the western Irish Caledonides and the sedimentary record of the collision, as preserved in the South Mayo Trough (Fig. 1). In this study we apply the U-Pb dating method to detrital zircon grains extracted from sandstones and conglomerates exposed in the South Mayo Trough to assess the evolving sources of sediment during and after this collisional event. We test the existing models for sediment derivation and settle the debate concerning the relative contributions of the colliding arc and the deformed Laurentian margin to the overall erosion budget.

Regional Setting

Arc-continent collision in Connemara occurred during the Early Ordovician and is considered to be the cause of the Grampian Orogeny of the British Isles and the Taconic Orogeny in North America (Williams, 1979; Dewey and Shackleton, 1984; Dewey and Ryan, 1990; Stockmal et al., 1990; Cawood and Suhr, 1992; Karabinos et al., 1998; Van Staal et al., 1998). The age of arc-continent collision in western Ireland is presently constrained to 475–465 Ma by the timing of magmatism and peak metamorphism in the Connemara Dalradian terrane, located immediately south of the outcrop of the Rosroe Formation (Cliff et al., 1996; Tanner et al., 1997; Friedrich et al., 1999a). The evolving geochemistry of the colliding Lough Nafooey Arc has been interpreted to indicate "soft collision" (i.e., subduction of the outer passive margin of Laurentia) prior to 480 Ma, followed by "hard collision", i.e., crustal thickening and high-grade metamorphism (Draut and Clift, 2001; Draut et al., 2004; Chew et al., 2007). Orogenic collapse by low-angle detachment faulting occurred after 468 Ma (Wellings, 1998; Clift et al., 2004). The Laurentian margin converted from a passive to an active state, located above a north-dipping subduction zone following the collision. As a result deposition of the sedimentary rocks studied here occurred significantly prior to final suturing of Iapetus in the Early Devonian (McKerrow et al., 1991). This well-defined tectonic framework makes interpretation of the evolving erosion patterns relatively straightforward.

The South Mayo Trough is unusual in being a sedimentary basin located in a suture zone, but without having been disrupted by strong deformation or metamorphism. Although it has been variously interpreted in the past there is now a general consensus that the trough represents the forearc to an intra-oceanic Lough Nafooey Arc (Dewey and Shackleton, 1984). We target three conglomerate units deposited in the immediate aftermath of the Grampian Orogeny, the Rosroe Formation, the Derryveeny Conglomerate and the Maumtrasna Formation (Fig. 2). These were deposited in the South Mayo Trough adjacent to the colliding arc and orogen. Deposition of the Rosroe Formation is dated as Early Llanvirn (lower *D. Artus* graptolite zone, 467–464 Ma according to the time scale of Tucker and McKerrow (1995) or 466.2–465 Ma according to the time scale of Cooper and Sadler (2004)). This unit comprises very coarse conglomerates and sandstones, containing abundant granite and volcanic rock clasts (Archer, 1977)(Fig. 3). The Rosroe Formation was interpreted originally to represent the deposits of large submarine fan deltas eroding a volcanic and plutonic arc source south of the modern outcrop (Archer, 1977; Archer, 1984). The Rosroe Formation has been correlated with the Derrylea Formation on the northern limb of the South Mayo Trough (Dewey, 1963; Dewey and Ryan, 1990)(Fig. 2) and eastwards into the Maumtrasna Formation. Up-section, the depositional environment of the South Mayo Trough shallows, culminating in the middle Llanvirn Mweelrea Formation, which comprises a >3-km-thick package of fluvial sandstones derived from the east from a rapidly eroding Dalradian source (Pudsey, 1984).

The Derryveeny Conglomerate (Figs. 2 and 3) contains abundant schist and foliated granite clasts, as well as granites similar to those seen in the Rosroe Formation (Graham et al., 1991). The provenance of sediments deposited during exhumation is not uniform, but shows a dominant influx from the east and southeast (Graham et al., 1991; Clift et al., 2002). The late Llanvirn age of sedimentation of the Derryveeny Conglomerate (464–443 Ma) is based on the presence of two clasts, which have yielded Rb-Sr muscovite-whole rock ages of 471 ± 8 Ma and 462 ± 7 Ma, and the presence of unconformably overlying Lower Silurian strata (Graham *et al.*

1991). Additional later Silurian and Devonian strike-slip faulting through Clew Bay also displaced the South Mayo Trough relative to the North Mayo Dalradian (Hutton, 1987; Van Staal et al., 1998; Williams, 2002), and some studies have argued for displacements of >1000 km along major strike-slip faults in the Caledonides of the British Isles (McKerrow and Elders, 1989). However, the current consensus on the faulting suggests that the amount of displacement was probably not large (Ryan et al., 1995).

Earlier Provenance Work

The provenance of the Rosroe Formation was initially constrained to be from south of the present outcrop based on the presence of granite clasts correlated with those known from within the Connemara Dalradian (Archer, 1984). Subsequently trace element and isotopic provenance data show that although these sedimentary rocks were derived from the Laurentian margin (i.e. from the Dalradian) palaeo-current measurements require dominant transport from the northeast, i.e. from the direction of possible sources in the North Mayo Dalradian and Ox Mountains (Fig. 1)(Clift et al., 2002; Williams, 2002).

The younger Derryveeny Conglomerate has a different clast assemblage and a transport direction froma local Dalradian source located to the southeast; presumably the Connemara Dalradian (Graham et al., 1991; Clift et al., 2002). Graham et al. (1991) therefore proposed that the lack of sediment flux from that direction before sedimentation of the Derryveeny Conglomerate precluded the presence of the Connemara Dalradian in its present location until after that time.

Analytical Strategy

The Rosroe Formation was sampled on the southern shore of Killary Harbour, 1.5 km from the centre of Leenane village at 53˚ 35.9'N, 9˚ 43.6'W (Irish grid reference L 85706, 62434). The Maumtrasna Formation was sampled by the roadside in the Partry Mountains at 53˚ 39.7'N, 9˚ 23.9'W (M 07660, 68958). The Derryveeny Conglomerate was sampled on the shore of Lough Mask at 53˚ 35.8'N 9˚ 26.1'W (M 05057, 61797). The sediments are all coarse grained, apparently proximal deposits.

Samples for U-Pb dating were analysed by laser ablation-inductively coupled plasma mass spectrometer (LA-ICPMS) using a New Wave 213 aperture imaged frequency quintupled laser ablation system (213 nm) coupled to an Agilent 750 quadrupole-based ICP-MS at University College, London. Real time data were processed using GLITTER™. Repeated measurements of external zircon standard Plesovic (reference age determined by thermal ionisation mass spectrometry (TIMS) is 337.13±0.37 Ma (Sláma et al., 2008)) and NIST 612 silicate glass (Pearce et al., 1997) were used to correct for instrumental mass bias and depth-dependent inter-element fractionation of Pb, Th and U. Data were filtered using standard discordance tests with a 10% cut-off.

The $^{206}Pb/^{238}U$ ratio was used to determine ages less than 1000 Ma and the $^{207}Pb/^{206}Pb$ ratio for grains older than 1000 Ma. Common Pb was determined by the ^{208}Pb method assuming a common Pb composition from the age-dependent Pb model of Cumming and Richards (1975). Data were processed using *Isoplot*™ (Ludwig, 2003). Uncertainties are typically in the range 1 to 3% and are shown for each analysis in Table 1. Around 100 grains were analyzed from each unit in order to provide a statistically robust image of what is potentially a complex source terrain, following the recommendations of Ruhl and Hodges (2005).

Results

The results of our analysis are given in Table 1 and are graphically displayed as probability density plots in Figure 4. These data can be compared with the known ranges of zircons in different parts of the Dalradian Supergroup, as well as the Moine Supergroup and the unmetamorphosed Torridonian Group, which characterize the Laurentian margin in the British Isles, and are thus potentially sources of sediment to the South Mayo Trough (Fig. 5). The age of the potential arc sources can be constrained to be older than the age of the Grampian Orogeny (the end of subduction volcanism)(Dewey and Mange, 1999) and younger than the proposed Tremadoc subduction initiation at ~495 Ma (Clift and Ryan, 1994; Chew et al., 2007). Comparison with the source ages helps to define and quantify the erosional flux from these different ranges.

The detrital grain ages in all three samples show clustering into roughly defined populations. There is a well defined younger grouping of 400–600 Ma, but no grains lie between ~600–750 Ma. The single most numerous population lies between 900–1300 Ma, which correlates with the well characterized Grenville Orogeny in eastern North America (McLelland et al., 1996), as well as parts of the British Isles (Brook et al., 1976; Daly, 1996). A third grouping is dated at 1300–2000 Ma. These ages correlate with zircons previously dated in the Dalradian Supergroup (Cawood et al., 2003). The Dalradian zircons have in turn been reworked from original crystalline sources that have been correlated to a number of smaller orogenic belts in eastern

Canada, namely the Torngat, New Quebec and Nagssugtoqidian (Scott, 1998; Whitehouse et al., 1998; Wardle et al., 2002). There are very few grains in our samples dating between 2.0 and 2.5 Ga, but an older population of ages greater than 2.5 Ga is common and correlates to ages known from the Lewisian Complex of NW Scotland and other parts of the Superior Craton of North America (Whitehouse et al., 1997; Corfu et al., 1998).

All three samples show a relatively modest proportion of younger grains that could have been eroded from the colliding Lough Nafooey Arc, comprising approximately 20%, 6% and 12% respectively in the Rosroe, Maumtrasna and Derryveeny Formations. The Maumtrasna Formation in particular is dominated by erosional flux from the Laurentian margin. Nonetheless, a number of coherent and significant differences are seen between the formations. The proportion of grains older than 2.0 Ga grains is fairly constant, but the Derryveeny Formation has the highest proportion of 1.3–2.0 Ga grains. In contrast, the Maumtrasna has the highest proportion (47%) of 800–1300 Ma grains.

Discussion

Sediment Sources

The new zircon data confirm the hypothesis that the vast majority of the sediment flux into the South Mayo Trough following the Grampian Orogeny was derived by erosion from the Laurentian margin, not from the colliding arc (Clift et al., 2002). The data also permit the source of the Laurentian debris to be constrained by comparison with the known ages of the Dalradian, Moine and Torridonian

Supergroup rocks (Fig. 5). The situation in western Ireland is potentially more complex than for many such suture zone basins because the South Mayo Trough is bordered both north and south by fragments of Laurentian crust (Fig. 1).

The Connemara and North Mayo Dalradian metamorphic terranes are considered to be metamorphosed fragments of the Laurentian margin (Lambert and McKerrow, 1976; Dewey and Shackleton, 1984; Harris et al., 1994). Connemara is inferred to be displaced from its original location and lies south of the units that comprise the Lough Nafooey Island Arc. This displacement cannot be the result of southward thrusting of high-grade metamorphic Connemara over South Mayo because much of this has never exceeded anchizone metamorphic conditions, although it is possible that Connemara might have been underthrust under the South Mayo Trough. The conventional explanation for the enigmatic position of Connemara today is that this was achieved by post-Grampian strike-slip tectonism that affected the Laurentian margin (e.g., the Southern Uplands Fault, the Fair Head-Clew Bay Line (equivalent to the Highland Boundary Fault in Scotland) and the Great Glen Fault (Hutton, 1987)).

The units comprising the Connemara Dalradian have been correlated to the upper parts of the type sections in the Scottish Highlands, i.e. the Southern Highland and Argyll Groups, with the lowermost Clifden Schist lying in the upper Appin Group (Leake and Tanner, 1994; Chew, 2001)(Table 2). In contrast, the lower parts of the supergroup dominate the North Mayo Dalradian exposure. Argyll Group rocks are seen, but Appin and Grampian Groups dominate and even the underlying Annagh Gneiss Complex (probable sub-Dalradian crystalline basement, similar to the Moine Supergroup) is identified (Daly, 1996). However, erosion has likely removed significant volumes of younger Argyll Group that would have covered the present exposure, although no Southern Highland Group is known from the structurally highest units under the Achillbeg Fault (Fig. 1).

The presence of pre-2.0 Ga grains in all three formations demonstrates that a purely Grampian Group or Moine/Annagh source is unlikely, as these ages are very rare in those units (Cawood et al., 2007). The numerous 800–1300 Ma population in all the conglomerates, and especially the Maumtrasna, is most characteristic of the Southern Highland and Argyll Groups (Cawood et al., 2003), implying preferential erosion of the upper part of the Dalradian into the South Mayo Trough. Consequently this argues against North Mayo being the primary source of Laurentian detritus, although we do recognize that erosion from North Mayo could have removed much of the younger material there. While erosion from Connemara would most readily explain the age population in the Derryveeny Formation, this is harder to apply to the Rosroe and Maumtrasna Formations because of the palaeo-current constraints.

We suggest that the Ox Mountains located around 50 km to the northeast, or equivalents in that region now buried by Carboniferous sedimentary rocks, might be appropriate sources because they are relatively local and expose mostly Southern Highland and Argyll Group rocks (Alsop and Jones, 1991). Sediment transport from that direction is also consistent with the SW-ward palaeo-current directions, which also argue against orthogonal sediment flux from North Mayo (Archer, 1984; Clift et al., 2002). We favour erosion from sources in the Ox Mountain/central Ireland region rather than Dalradian units now exposed in Scotland because of the coarse grain size of the conglomerates. Zircon ages alone cannot rule out the Scottish Dalradian as a source to the South Mayo Trough but the 350 km minimum transport distance does suggest that this is unlikely for the proximal facies observed. These regions could be sources to finer grained sedimentary rocks in the basin, or if strike-slip faulting had moved the South Mayo Trough far relative to the Dalradian since sedimentation, which is considered unlikely (Ryan et al., 1995). It is noteworthy that the ~820–670 Ma "Knoydartian" ages recorded in parts of the SW Scottish Highlands (Friend et al., 1997; Tanner and Evans, 2003) are not found in the Mayo Conglomerates, consistent with a more local provenance.

Grenville Sources?

Although the U-Pb dating of zircons does significantly constrain the provenance of the Lower Ordovician conglomerates and sandstones other data sets need to be considered for a more integrated and coherent image of orogenic erosion. By themselves the U-Pb ages suggest a dominantly Dalradian metamorphic provenance, yet the prevalence of granitoid clasts and of apatite grains would suggest strong influx from an igneous source. Heavy mineral studies show that the zircon populations in the Rosroe and Maumtrasna Formations comprise around 50% euhedral or subhedral grains, which are not typical of erosion from a metasedimentary source (Dewey and Mange, 1999). If these grains are not dominantly from the colliding arc, as might be expected, then their ages would suggest Grenville igneous sources, potentially in the foreland of the Grampian orogeny. A direct link to the Grenville in the Grampian foreland is hard, although potentially transport is only 100–150 km across strike. This is because sediment flux from these sources would have to cross the core of the Grampian orogeny. However, this is not impossible, because major rivers are known to cut across active mountains, e.g. , the Sutlej River and Himalaya, yet these are not common features and are not known from modern arc-continent collisional orogens.

Igneous sources with the characteristic 900–1300 Ma ages are known from the Gardar Province of southern Greenland (Blaxland et al., 1978), although Grenville age sources from East Greenland are generally too old to make good matches for the grains seen in South Mayo (Kalsbeek et al., 2000). The texturally immature and coarse-grained nature of the sediment argues against erosion from far distant sources, while the palaeo-flow direction from the ENE makes erosion from the classic North American Grenville exposures impossible (Fig. 1)(Hoffman, 1989; Rivers, 1997). A clear resolution of this enigma is not currently apparent. Nonetheless, we presently favour a dominant reworking of Grenville igneous zircons through the Dalradian metasedimentary sequences, with a mostly local provenance from the ENE, supported by the sedimentary facies and the U-Pb age data.

Ordovician Grains

The youngest grain population in each of the units warrants further inspection in order to assess a possible arc source. Figure 7 shows the age spectrum for the 450–600 Ma time span, with the major tectonic events known from the region marked to provide context. The diagram highlights the short time lag (and potentially rapid exhumation) between zircon crystallization and sedimentation for the Maumtrasna and Rosroe Formations. However, if the zircon grains were volcanic and not plutonic then the short time lag would not be significant in limiting exhumation rates. Zircons in the Maumtrasna and Rosroe Formations correlate in age with syn-collisional plutons in Connemara (Tanner et al., 1997; Friedrich et al., 1999b) and confirm some erosion of arc debris into the South Mayo Trough. However, the Derryveeny Formation grains are resolvably older, peaking around 540 Ma (cf., 470 Ma), close to the end of extension on the Laurentian margin and the onset of seafloor spreading (McKerrow et al., 1991; Cawood et al., 2001). Critically, these pre-date the apparent initiation of subduction in the Iapetus and so cannot be linked to an early phase of intra-oceanic arc magmatism. Few granites of this age are known from the Dalradian, with the nearest suitable known sources being the "Older Granites" of Barrow (1893), generally dating around 600 Ma (Oliver et al., 2008), but with some as young as 588 Ma in Scotland (Braeval Granite) (Kinny et al., 2003). Rift-related magmatism dating to as young as 550 Ma is however known from the Newfoundland sector of the Laurentian margin (Cawood et al., 2001). We thus interpret these grains to represent erosion from intrusions linked to break-up of the Laurentian margin and not to the colliding arc, because they predate the generally accepted age of subduction initiation and are synchronous with break-up, albeit younger than any granite so far dated. We suggest that by Derryveeny times erosion from the colliding arc had ceased entirely. Most likely the extension and subsidence that occurred at the time of orogenic collapse and subduction polarity reversal (post-470 Ma) would have buried or submerged any residual topography.

Age of Sedimentation

The new U-Pb ages provide some control on the age of sedimentation. The Rosroe Formation is dated at 464–467 Ma based on graptolites (Graham et al., 1989), which is consistent with the youngest zircon grain age of 465 ± 9.9Ma. The short time delay of no more than 11 m.y. between zircon crystallization and sedimentation implies rapid exhumation rates. Sedimentation of the Derryveeny Conglomerate is dated loosely as being post Llanvirn and pre-Llandovery (Graham et al., 1989)(i.e., 460–443 Ma) while the youngest grain is dated at 512 ± 10 Ma. This implies much slower rates of long-term exhumation by Derryveeny times, assuming that the zircons are not of volcanic origin.

The youngest grain dated from the Maumtrasna Formation yields an age of 452.3 ± 6 Ma, which is younger than the Llanvirn depositional age (464–465 Ma) most recently assigned by Graham (1987). The age of the Maumtrasna Formation has been controversial, with ages ranging from Llandeilo, Caradoc and even Devonian being proposed (Williams, 1972; Max et al., 1978; Williams, 1980). Mapping by Graham (1987) however demonstrated that the Maumtrasna Formation underlies the Glenummera Formation (Fig. 2). This in turn is dated as being deposited during the Llanvirn, no later than 463.6 Ma according to the graptolite assignment of Harper et al. (1988), as applied to the more recent timescale of Cooper and Sadler (2004). However, this particular grain age is around 13% discordant and cannot be used as an accurate constraint on the age of crystallization or sedimentation of the Maumtrasna Formation, beyond being a young "arc-like" rather than Dalradian grain.

Conclusions

New U-Pb ages from zircon grains extracted from three sandy conglomerate units in the South Mayo Trough allow models for erosion during and after the Grampian Orogeny to be tested. As in Taiwan erosion during the peak orogenic and early collapse phase of arc collision is dominated by erosion from the deformed and metamorphosed passive margin, not the colliding arc. Grain ages that lie close to the depositional ages confirm suggestions of rapid exhumation at that time (Friedrich et al., 1999a; Power et al., 2001). However, our grain populations, together with the

SSW-directed palaeo-currents indicate that during deposition of the Maumtrasna and Rosroe Formations the dominant flux of material was along strike from the Ox Mountains or similar ranges to the northeast, not orthogonally into the basin from the Connemara Dalradian. In this respect sediment dispersal mirrors patterns seen in modern arc collision zones, such as Taiwan. After 460 Ma when the Derryveeny Formation was deposited erosion is completely of Laurentian provenance and is consistent with erosion from the Connemara Dalradian. Exhumation rates appear to have fallen rapidly by this time. The North Mayo Dalradian does not appear to have been an important source of sediment to this particular basin, but could have supplied material along strike, presumably to equivalent basins located to the southwest. Erosion from the colliding arc is generally modest and suggests that very little arc crust is destroyed during its accretion to the Laurentian margin.

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Figure Captions

Figure 1. Regional geological map of western Ireland showing the Connemara and North Mayo metamorphic terranes separated by the South Mayo volcanic island arc terrane. The strike-slip faulted boundary between the Connemara and South Mayo terranes is buried under Silurian strata, while the Achill Beg Fault separates low grade arc and trench rocks of South Mayo from the high grade rocks of North Mayo. Sample locations are shown with a star.Inset maps show (1) the location of the Grenville Province in North America (Hoffman, 1989) and (2) the location of the study area within the British Isles,

Figure 2. Schematic stratigraphy of the South Mayo Trough Ordovician, showing the variability from south to north limb of the syncline and time equivalent units. A star marks sampled units.

Figure 3. Field photographs of the outcrops sampled in this study (A) Rosroe Formation in Killary Harbour, 1 km west of Leenane, (B) Derryveeny Conglomerate on shores of Lough Mask, and (C) Maumtrasna Formation on side of road in Partry Mountains, northwest of Tourmakeady. See Figure 1 for locations. Detailed grid coordinates are provided in the text.

Figure 4. Probability density plots of the U-Pb ages of detrital zircon grains separated from each of the studied formations. Lowermost panel shows averaged age plots for the upper and lower parts of the Dalradian Supergroup, respectively the Southern

Highland Group (Cawood et al., 2003) and the Grampian Group (Cawood et al., 2003; Banks et al., 2007).

Figure 5. Probability density plots of the U-Pb ages of zircon grains taken from the various possible source terrains within Laurentia close to the South Mayo Trough. Ages of the Moine Supergroup are from Friend et al. (2003) and Cawood et al. (2003; 2004). The Upper Dalradian ages (Southern Highland Group) are from Cawood et al. (2003). Middle Dalradian (Appin and Argyll Groups) are from Loewy et al. (2003) and Cawood et al. (2003). Lower Dalradian (Grampian Group) ages are from Cawood et al. (2003) and Banks et al. (2007). Torridonian ages are from Rainbird et al. (2001).

Figure 6. Pie diagrams showing the relative proportions of the different major age populations within each of the samples analyzed.

Figure 7. Probability density plots of the U-Pb ages of detrital zircon grains between 450 and 600 Ma. Ages of the Connemara gabbros are from Friedrich et al. (1999b). Age of the Oughterard Granite is from Tanner et al. (1997) and Friedrich et al. (1999b). Age of the Portsoy and Keith Granites are personal communications (J. Mendum in Strachan et al. (2002)). Age of the Carn Chuinneag granite is from Oliver et al. (2008).

Table 1. U-Pb isotopic analytical data for the zircon grains analysed in this study.

Table 2. Summary chart showing the major units of the Dalradia stratigraphy exposed in the vicinity of the South Mayo Trough. Data compiled from Geological Survey of Ireland, sheet 11 memoir.

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